

Appendix 6

Development and Analysis of Target Fish Community Models to Evaluate the Status of the Existing Fish Communities in the Upper and Lower Souhegan River, New Hampshire

Introduction

The Northeast Instream Habitat Program (NEIHP) at the University of Massachusetts conducted an analysis of fish habitat in the Souhegan River in an effort to identify and define the flow dependency of the native fish fauna within the Souhegan River as part of the Souhegan River Protected Instream Flow (PISF) Study. This analysis entailed assessing changes in fish habitat availability at various stream flows, and using multivariate statistics to determine which physical habitat characteristics are most suitable for individual or species (or species groups) of fishes. Once these relationships were established, a habitat simulation model, MesoHABSIM (Parasiewicz, 2001) was used to determine the relationships between instream flow conditions, physical habitat, and the fish community within the river (Souhegan PISF Report). An approach, known as Target Fish Community (TFC) modeling (Bain and Meixler, 2000), was used: to identify the native fluvial species that were considered in the MesoHABSIM modeling process; to evaluate the condition of the existing fish community within the Souhegan River; and guided potential habitat rehabilitation measures and instream flow regulation recommendations. We created Target Fish Communities for the Upper and Lower Souhegan River using the method developed by Bain and Meixler (2000) on the Quinebaug River in Connecticut and Massachusetts.

Developing TFC models consisted of multiple steps. First, a list of species expected or with the potential to occur within the project river was compiled. Next, a group of rivers, physically and zoo-geographically similar to the investigated river and relatively un-impacted, were chosen as references. Existing fish collection data from these reference rivers were then used to generate the TFC models. To calculate the models, a weighted ranking procedure was applied to these data sets to determine the species compositions and relative abundances of fish expected to occur within the project river for the un-impaired conditions. The computational framework of TFC models accounted for spatial and temporal variations of the native communities within the reference rivers and created robust, inter-annual representations of the expected native fauna compositions of the Upper and Lower Souhegan River.

The resulting TFC models were then compared to the existing assemblages of fish species found within the Upper and Lower Souhegan River, respectively, based on fish capture and observation data collected from multiple locations and mesohabitat types throughout the river. Observations of the existing fish communities were made by the Northeast Instream Habitat Program using stream-side electrofishing gear and pre-positioned grids within the Upper Souhegan River, and through underwater observations made while snorkeling on the Lower Souhegan River. The status and condition of the Upper and Lower Souhegan River fish communities¹ were evaluated based on these comparisons.

We present here two target fish communities, created for the Upper and Lower portions of the Souhegan River, New Hampshire. Their development processes are outlined, the resulting communities are presented, and comparisons are made between the TFC models and the

¹ Despite their unique meanings in community ecology applications, as defined by Fauth et al. (1996), the terms “community” and “assemblage” are used interchangeably in this paper when referring to the fish fauna of the Souhegan River and TFC models.

existing fish communities to identify deviations from target conditions and to evaluate the status of the Souhegan River fish communities.

Methods

Study Area

The study area encompasses the main stem of the 171 square mile Souhegan River watershed from the Massachusetts-New Hampshire border downstream (north-northeast) to its confluence with the Merrimack River in Merrimack, New Hampshire. Based on an initial reconnaissance survey and MesoHABSIM habitat mapping of the river in 2004, the river was divided into eleven representative sites (Figure 1). In the area downstream of site 5, the river exhibits multiple geo-physical differences (e.g. stream order, gradient, dominant substrate type) from the river upstream of that point. At the confluence of Stoney Brook (just upstream of site 5) the stream order of the river changes from third to fourth order, the valley begins to widen, and the gradient of the river becomes less steep. There is also a noticeable change in the dominant substrate type in the river downstream of this point, from large cobble and boulders with bedrock outcrops upstream, to sand and fine gravel downstream. These sudden changes in gradient, stream order, and dominant substrate type coincide with the approximate location of the Milford-Souhegan glacial-drift aquifer, an area of unconsolidated glacial-drift deposits consisting primarily of stratified sand and gravel overlain by more recent alluvium (Harte, 1992). The combined effects of gradient and stream order changes and the sudden change in surficial geology create differences in the available habitat types between the upper and lower portions of the river. Furthermore, a zoogeographic division of Level III Ecoregions (Omernik, 1987) occurs between the Upper and Lower Souhegan River². The upper portions of the Souhegan River are within Ecoregion 58, the Northeastern Highlands, and the lower portions of the river extend into Ecoregion 59, the Northeastern Coastal Zone (Figure 1). Consequently, differences between the fish communities of the Upper and Lower Souhegan River were expected to occur. To account for the expected difference in the fish communities associated with these different habitat types, separate TFC models were developed for the Upper and Lower Souhegan River.

Fish List

A list of species currently or historically found or with the potential to exist within the Souhegan River was compiled using fish distribution references, historical records, and recent collection records (Schmidt, 1986; Scarola, 1987; Hartel et al., 2002; NAI, 2004).

The fish species within the TFC and the Souhegan River existing fish communities were organized into specialized habitat use and pollution tolerance classification guilds based on classifications assigned by Bain (2000) through an extensive literature review (Scott and Crossman, 1973; Pflieger, 1975; Lee et al., 1980; Trautman, 1981; Becker, 1983; Burr and Warren, 1986; Robinson and Buchanon, 1988; Jenkins and Burkhead, 1994; Halliwell et al.,

² Determination of the zoo-geographic similarity of areas is based on an analysis of geology, physiography, vegetation, climate, soils, land use, wildlife and hydrology to identify ecologically similar regions, or Ecoregions

1999). Creek chub, fallfish, longnose dace, longnose sucker, and slimy sculpin were reclassified as fluvial specialists in this study, as in previous target fish community studies within this region, based on their local habitat use patterns (Lang et al., 2001; Kearns et al., 2005). Fish species were also classified based on their thermal requirements, determined from a review of the literature pertinent to the fishes of the northeast region (Scarola, 1987; Halliwell et al., 1999; Langdon, 2001; Hartel et al. 2002; NAI, 2004).

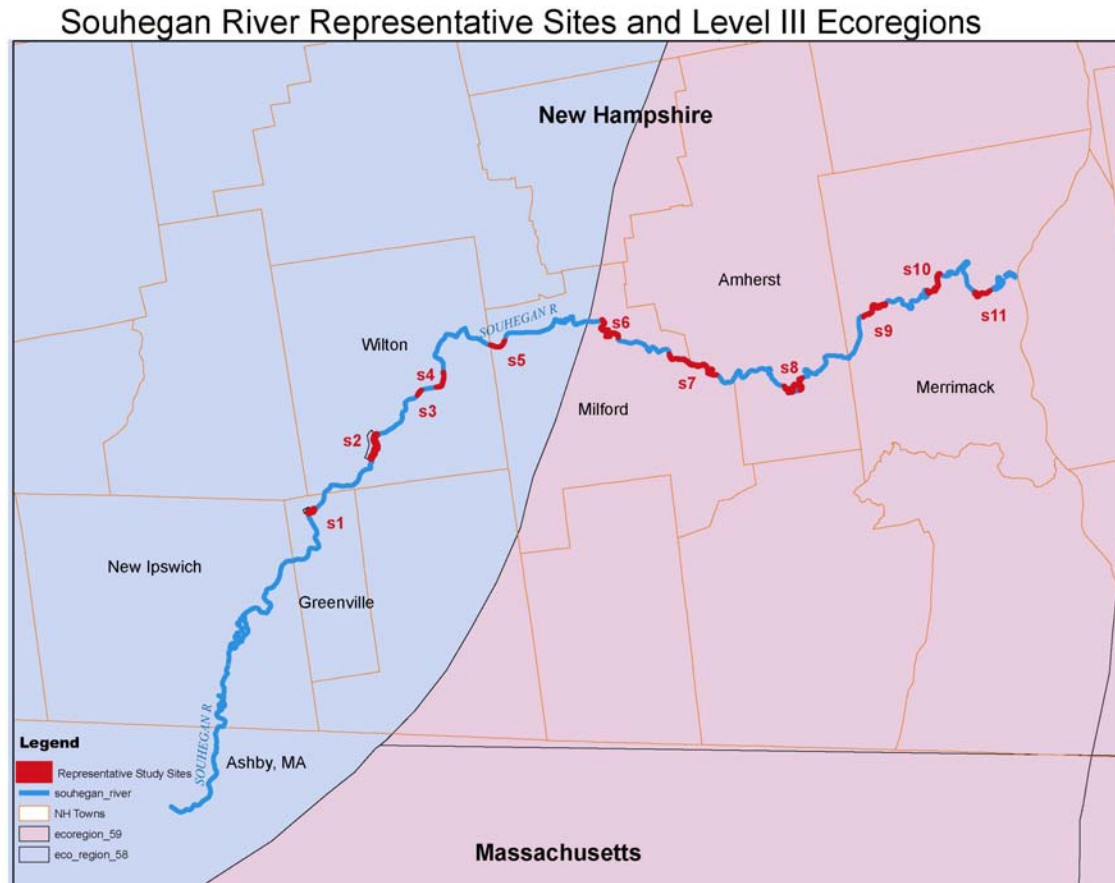


Figure 1. Souhegan River with representative sites and Level III Ecoregions

Reference River Selection

Several rivers, similar in geo-physical character and zoo-geographic regional location to the Upper Souhegan River and with relatively few ecological disturbances were chosen as references for the Upper Souhegan. Similarly, a second set of reference rivers were chosen for the Lower Souhegan. Historical fish collection data from these reference rivers were then used to calculate TFC models for the Upper and Lower Souhegan River, respectively. Initial selections of these rivers were made using ArcMap (ESRI, Inc., 1999-2004) Geographic Information System (GIS) software tools to create a geoprocessing model, the Reference

River Selection Model (RRSM). Selection of a stream as a suitable reference river was dependent upon a river having five geo-physical attributes (drainage area size, stream order, gradient class, elevation class, and percent of calcareous geologic formations) existing in similar magnitude to those of the Upper or Lower Souhegan River, and occurring within the same zoo-geographic regional location, Level III Ecoregion (Omernik, 1987). The quantitative parameters of these attributes within the Upper and Lower Souhegan River were identified (Table 1) and entered into the RRSM as selection criteria. The model was then applied to a stream classification GIS data layer created by The Nature Conservancy (TNC) (TNC, 2003) to select rivers meeting the defined criteria. Rivers selected by the RRSM meeting the defined criteria of the Upper Souhegan were then considered as potential reference rivers for the Upper river while those meeting the defined criteria of the Lower Souhegan were considered potential references for the Lower river. The conditions of these rivers were then investigated to determine their suitability as reference rivers.

Table 1. Parameters of the geo-physical and zoo-geographic attributes of the Upper and Lower Souhegan River: Criteria for the Reference River Selection Model (RRSM).

Lower Souhegan River

Physical Attribute	Selection Parameters
Drainage Area	80-171 sq. miles
Stream Order	4
Gradient Class*	1
Elevation Class**	1
% Calcareous Geology	0
Level III Ecoregion	59

Upper Souhegan River

Physical Attribute	Selection Parameters
Drainage Area	7-80 sq. miles
Stream Order	2-3
Gradient Class	1-2
Elevation Class	1-2
% Calcareous Geology	0
Level III Ecoregion	58

*Gradient Classes: 1 = 0-0.5%, 2 = 0.5-2%, 3 = 2-4%, 4 = 4-10%, 5 = >10%

**Elevation Classes: 1 = 0-800ft., 2 = 800-1700ft., 3 = 1700-2500ft., 4 = 2500ft.+

Using the definition of Kearns et al. (2004)³, the ecological status of the selected rivers was assessed by judgments of natural resource and fisheries professionals. Rivers that were found to be of poor ecological quality were deemed “impacted” and eliminated from consideration as potential reference rivers. The rivers, from which adequate fish collection data (having more than 10 individuals of the most common species in the sample (Bain & Meixler, 2000)) could not be obtained, were also eliminated. Fish collection data from the remaining reference rivers were then used to develop the Souhegan River TFC models. Data from the Upper Souhegan reference rivers served to create the Upper Souhegan TFC (U-TFC), while those from the Lower Souhegan reference rivers were used to create the Lower Souhegan TFC (L-TFC).

³ In a similar analysis on the Housatonic River (Kearns et al. 2004), quality rivers were defined as being “relatively unimpaired, undammed, and undeveloped with few water withdrawals, good water quality, and a similar temperature regime.”

Target Fish Community Development

The fish data used to develop the TFC models were collected by the New Hampshire Department of Environmental Services (NHDES), the New Hampshire Fish and Game Department (NHFGD), and the Massachusetts Division of Fisheries and Wildlife (MDFW) using the standard backpack electrofishing techniques of their respective agency. Geographic coordinates of the fish data sample sites were superimposed over the selected portions of the reference rivers within Arc GIS. Maps were then generated showing the locations of the sampling sites. Fish data that did not originate from selected suitable portions of the reference rivers were not considered in the formation of the TFC models.

Expected proportions of fish species were generated using the method developed by Bain & Meixler (2000). The total number of fish at each site was summed and the totals of each species were divided by this sum, yielding a proportion of the total catch. These species proportions were summed for all sites and the sums of the proportions were then ranked with the species having the greatest sum ranked “1”. All non-native fish species were removed from the data sets prior to calculations of expected proportions. Despite the removal of these species, all of the remaining species maintained the same numerical rank. Next, the reciprocal of each species rank (1/rank) was taken and all of these reciprocals were summed. The reciprocal rank of each individual species was then divided by the total sum of all reciprocal ranks to determine the expected proportion of each individual species.

Souhegan River Fish Sampling

A survey of the Upper Souhegan River fish community was conducted in July and August of 2005. Surveys were conducted using 6 m², pre-positioned electrofishing grids. This method had been proven by Bain (1985) as an effective method of sampling fish for habitat related studies, and has been successfully applied by NEIHP to investigate fish community and habitat relationships on the Quinebaug, Pomperaug, and Eightmile Rivers in Connecticut.

A survey of the Lower Souhegan River fish community was conducted in August of 2005. Because of the consistently deep water found throughout the Lower Souhegan, grid electrofishing was not possible. The Lower Souhegan was, as a result, surveyed using snorkeling equipment to make underwater observations of fish within previously selected HMU located throughout six representative sites of the Lower river in a method similar to the one used by Bult et al. (1998).

Existing Fish Community Evaluation

Evaluation of the status of the fish fauna in the Souhegan River was accomplished using Novak and Bode’s (1992) percent model affinity procedure. This procedure yields values from 0 to 100 to describe the extent to which the Souhegan River fish community is similar to the TFC. Higher percent model affinity values indicate higher degrees of similarity between the communities. These values are calculated as:

$$\text{Percent similarity} = 100 - 0.5 (\text{Sum} | \text{target P} - \text{observed P} |)$$

where: P = proportions of each species in the community or collection

The TFC and the existing fish communities were then compared again based on the proportions of habitat use, pollution tolerance, and thermal regime classification guilds within the communities. Differences between proportions of individual species in the TFC models and the existing fish communities of the Souhegan River were also analyzed to evaluate the status of individual fish species within the river. An analysis of the percentage differences between target proportions (TFC) and existing proportions of fish species was used to determine which were underrepresented, existing in expected proportions, or overly abundant within the Upper and Lower Souhegan River. Differences are calculated as:

$$\text{Percentage difference} = | \text{target P} - \text{observed P} | / \text{target P}$$

Species existing in proportions more than 50% lower than expected were considered underrepresented and species existing in proportions more than 50% higher than expected were considered overly abundant. Missing native species and the presence of non-native or introduced fish species and their proportion of the existing community were identified.

Results

Fish List

Based on our review of fish distribution references, historical records, and recent collection records, thirty-five species, from eleven different families, were found to occur historically or currently, or were considered to have the potential to occur within the Souhegan River (Table 2). The list contains a variety of species, both native and introduced, with a full range of habitat use, pollution tolerance, and thermal regime classifications.

Quality Reference Rivers

Table 3 lists all potential reference rivers found to be geo-physically and zoo-geographically similar to the Upper Souhegan River and Lower Souhegan River and gives reasons for those that were rejected. Those that were not rejected make up the quality reference rivers from which fish data were used to develop the Upper and Lower Souhegan River TFC models.

Table 2. Species expected or with potential to occur in the Souhegan River. Native (N) or introduced (I) statuses, fluvial specialist (FS), fluvial dependent (FD), or macrohabitat generalist (MG) habitat use classifications, intolerant (I), moderate/intermediate (M), or tolerant (T) pollution tolerances, and Cold, Cool*, or Warm water thermal regimes are given for each species.

<u>Family</u>	<u>Common name</u>	<u>Genus</u>	<u>Species</u>	<u>Native or Introduced</u>	<u>Habitat use classification</u>	<u>Pollution tolerance</u>	<u>Thermal regime</u>
<u>Petromyzontidae</u>	Sea lamprey	<i>Petromyzon</i>	<i>marinus</i>	N	FD		
<u>Anguillidae</u>	American eel	<i>Anguilla</i>	<i>rostrata</i>	N	FD	T	Cool
<u>Clupeidae</u>	Alewife	<i>Alosa</i>	<i>pseudoherangus</i>	N	FD		
	American shad	<i>Alosa</i>	<i>sapidissima</i>	N	FD		
<u>Salmonidae</u>	Rainbow trout	<i>Oncorhynchus</i>	<i>mykiss</i>	I	FD	I	Cold
	Atlantic salmon	<i>Salmo</i>	<i>salar</i>	N	FS	I	Cold
	Brown trout	<i>Salmo</i>	<i>trutta</i>	I	FD	I	Cool
	Brook trout (char)	<i>Salvelinus</i>	<i>fontinalis</i>	N	FS	I	Cold
<u>Escocidae</u>	Redfin pickerel	<i>Esox</i>	<i>americanus</i>	N	MG	M	Warm
	Chain pickerel	<i>Esox</i>	<i>niger</i>	N	MG	M	Warm
<u>Cyprinidae</u>	Common carp	<i>Cyprinus</i>	<i>carpio</i>	I	MG	T	Warm
	Common shiner	<i>Luxilus</i>	<i>cornatus</i>	N	FD	M	Cool
	Golden shiner	<i>Notemigonus</i>	<i>crysoleucas</i>	N	MG	T	Cool
	Spottail shiner	<i>Notropis</i>	<i>hudsonius</i>	N	MG	M	Cool
	Blacknose dace	<i>Rhinichthys</i>	<i>atratulus</i>	N	FS	T	Cool
	Longnose dace	<i>Rhinichthys</i>	<i>cataractae</i>	N	FS	M	Cool
	Creek chub	<i>Semotilus</i>	<i>atromaculatus</i>	N	FS	T	Cool
	Fallfish	<i>Semotilus</i>	<i>corporalis</i>	N	FS	M	Cool
<u>Catostomidae</u>	White sucker	<i>Catostomus</i>	<i>commersoni</i>	N	FD	T	Cool
	Longnose sucker	<i>Catostomus</i>	<i>catostomus</i>	N	FS	M	Cold
	Creek chubsucker	<i>Erimyzon</i>	<i>oblongus</i>	N	FS	I	Cool
<u>Ictaluridae</u>	Yellow bullhead	<i>Ameiurus</i>	<i>natalis</i>	I	MG	T	Warm
	Brown bullhead	<i>Ameiurus</i>	<i>nebulosus</i>	N	MG	T	Warm
	Margined madtom	<i>Noturus</i>	<i>insignis</i>	I	MG	T	Warm
<u>Centrarchidae</u>	Banded sunfish	<i>Enneacanthus</i>	<i>obesus</i>	N	MG	M	Warm
	Redbreast sunfish	<i>Lepomis</i>	<i>auritus</i>	N	MG	M	Warm
	Pumpkinseed	<i>Lepomis</i>	<i>gibbosus</i>	N	MG	M	Warm
	Bluegill	<i>Lepomis</i>	<i>macrochirus</i>	I	MG	T	Warm
	Smallmouth bass	<i>Micropterus</i>	<i>dolomieu</i>	I	MG	M	Warm
	Largemouth bass	<i>Micropterus</i>	<i>salmoides</i>	I	MG	M	Warm
	Black crappie	<i>Pomoxis</i>	<i>nigromaculatus</i>	I	MG	M	Warm
<u>Percidae</u>	Swamp darter	<i>Etheostoma</i>	<i>fusiforme</i>	N	MG	M	Warm
	Tesselated darter	<i>Etheostoma</i>	<i>olmstedii</i>	N	FS	M	Cool
	Yellow perch	<i>Perca</i>	<i>flavescens</i>	N	MG	M	Cool
<u>Cottidae</u>	Slimy sculpin	<i>Cottus</i>	<i>cognatus</i>	N	FS	I	Cold

* Species tolerating a wide range of water temperatures from cold to warm (eurythermal).

Table 3. The list of rivers identified as physically and zoo-geographically similar to the Souhegan River (potential reference rivers) and reasons for elimination of those not selected as quality reference rivers.

Upper Souhegan Reference rivers	Selected as Reference river	Reason for rejection
Ashuelot River, SB	No	Impacted
Blackwater River, NH	No	Lack of fish data
Burnshirt River, MA	Yes	--
Chickley River, MA	Yes	--
Cold River, MA	Yes	--
Contoocook River, North Branch, NH	No	Impacted
Cocheco River, NH	No	Impacted
Indian River, NH	No	Lack of fish data
Mascoma River, NH	Yes	--
Piscataquog River, Middle Branch, NH	Yes	--
Piscataquog River, South Branch, NH	Yes	--
Soucook River, NH	No	Insufficient fish data
Sugar River, North Branch, NH	No	Lack of fish data
Suncook River, NH	Yes	--
Swift River, East Branch, MA	Yes	--
Westfield River, East Branch, MA	Yes	--
Westfield River, Middle Branch, MA	Yes	--
Westfield River, West Branch, MA	Yes	--

Lower Souhegan Reference rivers	Selected as Reference river	Reason for rejection
Assebet River, MA	No	Impacted
Burnshirt River, MA	No	Insufficient fish data
Charles River, MA	No	Impacted
Neponset River, MA	No	Impacted
Quaboag River, MA	Yes	--
Quinnebaug, River, MA & CT	No	Impacted
Quinnipiac River, CT	Yes	--
Soucook River, NH	Yes	--
Suncook River, NH	No	Insufficient fish data
Taunton River, MA	No	Impacted
Ware River, MA	Yes	--
Willimantic River, CT	Yes	--

Upper Souhegan River Target Fish Community

The Upper Souhegan River TFC (U-TFC) was created using fish collection data from the eleven quality upper reference rivers identified in Table 3. The resulting community was a diverse one dominated by fluvial species. The ten most abundant species in the U-TFC were: blacknose dace (29%), longnose dace (15%), common shiner (10%), common white sucker (7%), fallfish (6%), slimy sculpin (5%), Eastern brook trout (4%), longnose sucker (4%), redbreast sunfish (3%), and Atlantic salmon (3%). The remaining species consisted of brown bullhead, creek chub, yellow perch, pumpkinseed sunfish, golden shiner, Eastern chain pickerel, spottail shiner, and American eel, and accounted for a combined total of 14% of the expected community. A chart representing the U-TFC is shown in Figure 2. The community is comprised of fluvial specialist (67%), fluvial dependent (18%), and macrohabitat generalist (15%) species (Figure 3). The final species list, mean ranks, and expected proportions of the U-TFC are presented in Table 4.

Lower Souhegan River Target Fish Community

The Lower Souhegan River TFC (L-TFC) was created using fish collection data from the five quality lower reference rivers also identified in Table 3. The L-TFC is as equally diverse as the U-TFC and is also dominated by fluvial species. The ten most abundant species in the L-TFC were: common white sucker (32%), fallfish (15%), common shiner (10%), blacknose dace (8%), longnose dace (6%), yellow perch (5%), pumpkinseed sunfish (4%), brown bullhead (3%), tessellated darter (3%), and Eastern chain pickerel (3%). The remaining species, redbreast sunfish, golden shiner, creek chubsucker, American eel, spottail shiner, and Eastern brook trout account for a combined total of 11% of the expected community (Figure 4). The community is comprised of fluvial specialist (35%), fluvial dependent (42%), and macrohabitat generalist (23%) species (Figure 5). The data used to generate the L-TFC, calculated mean ranks, and expected proportions are displayed as Table 5.

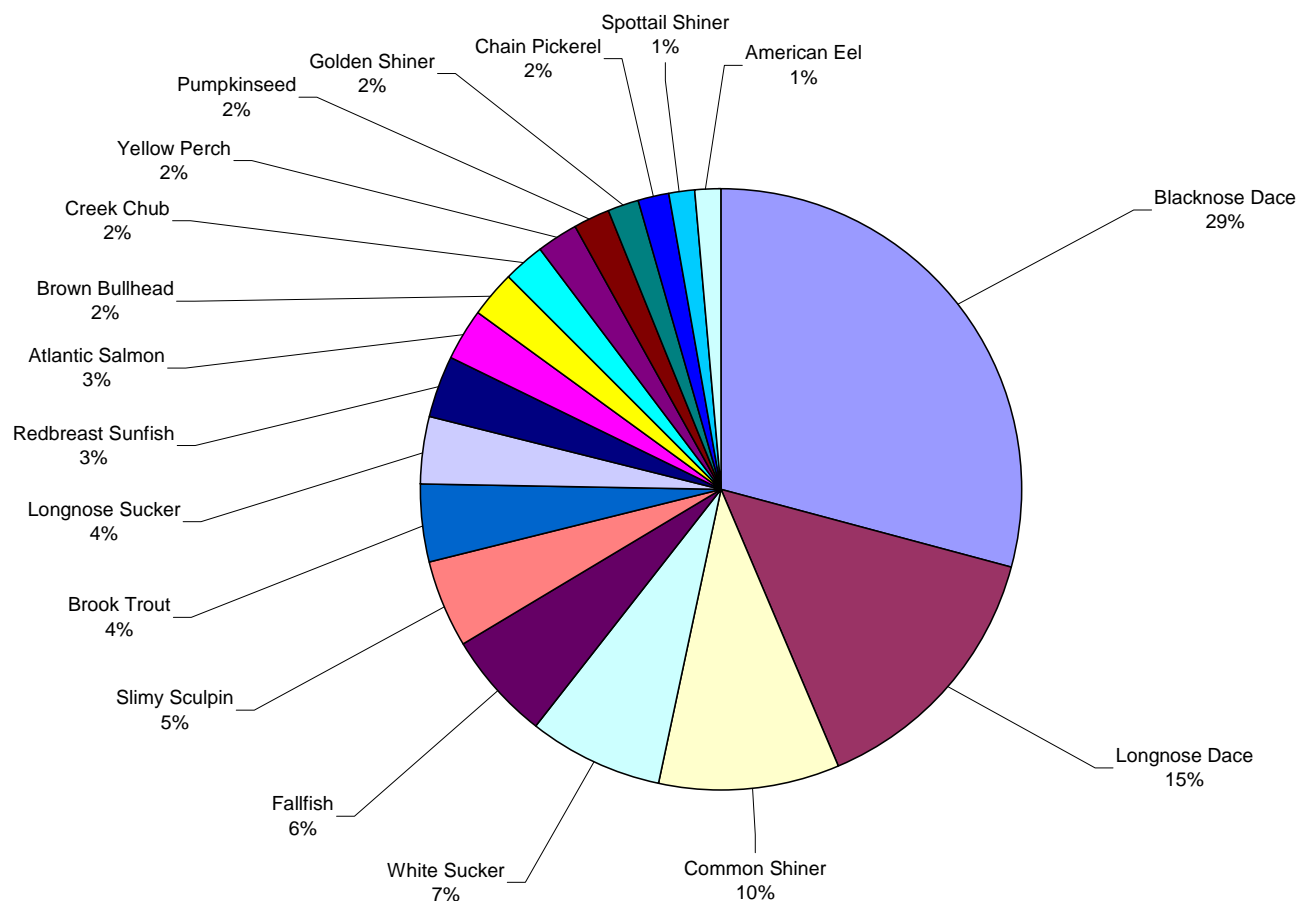


Figure 2. Upper Souhegan River Target Fish Community (U-TFC).

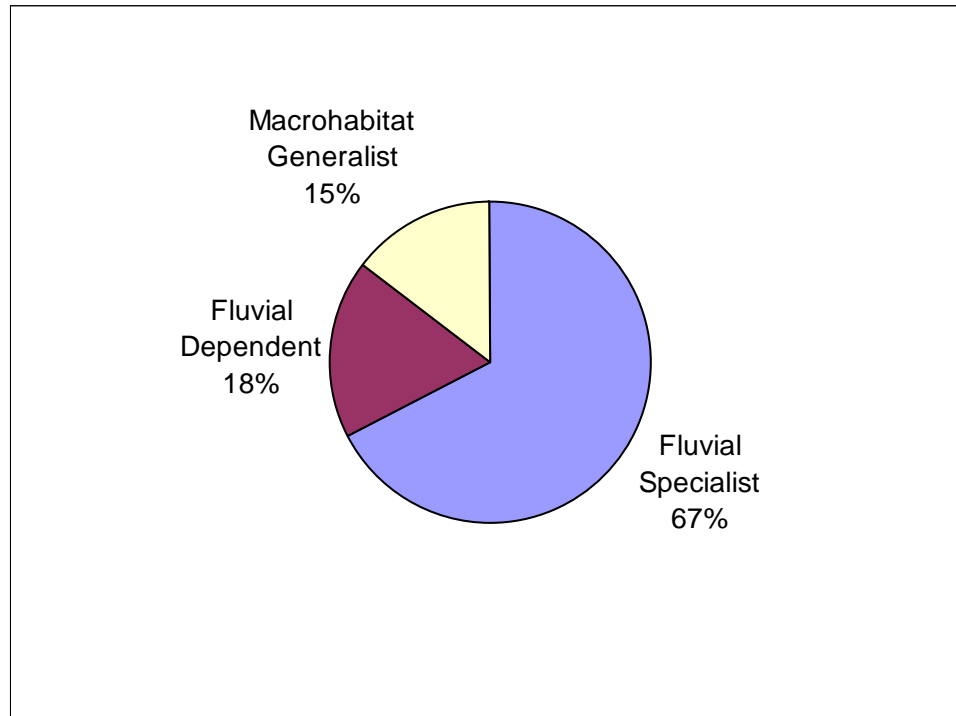


Figure 3. U-TFC based on habitat use classification guilds.

Table 4. Fish captures in reference rivers used for development of the Target Fish Community for the Upper Souhegan River with calculated mean ranks and expected proportions.

Common Name	Scientific Name	Burnshirt River	Chickley River	Cold River	Mascoma River	Piscataquog River, M.B.	Piscataquog River, S.B.	Suncook River	Swift River, E.B.	Westfield River, E.B.	Westfield River, M.B.	Westfield River, W.B.	Mean Rank	Expected Proportion
Blacknose Dace	<i>Rhinichthys atratulus</i>	4	54	159	24	89	138	4	85	111	105	95	1	29%
Longnose Dace	<i>Rhinichthys cataractae</i>	2	17	17	18	50	102	1	94	31	24	58	2	15%
Common Shiner	<i>Luxilus cornutus</i>	6		41	2	71	109	31		9	3	6	3	10%
White Sucker	<i>Catostomus commersoni</i>	39	4	15	18	7		3	70	22	30	27	4	7%
Fallfish	<i>Semotilus corporalis</i>	114			3	35	14	5	44			22	5	6%
Slimy Sculpin	<i>Cottus cognatus</i>		35	27						9	17	12	6	5%
Brook Trout	<i>Salvelinus fontinalis</i>		19	7					18	5	11	10	7	4%
Longnose Sucker	<i>Catostomus catostomus</i>		11	26		11	38						8	4%
Redbreast Sunfish	<i>Lepomis auritus</i>				2			10					9	3%
Atlantic Salmon	<i>Salmo salar</i>					23	42						10	3%
Brown Bullhead	<i>Ameiurus nebulosus</i>	19		2		1			13			1	12	2%
Creek Chub	<i>Semotilus atromaculatus</i>			9	1			2			4		13	2%
Yellow Perch	<i>Perca flavescens</i>								33				14	2%
Pumpkinseed	<i>Lepomis gibbosus</i>					2	2		13	1		5	15	2%
Golden Shiner	<i>Notemigonus crysoleucas</i>			6		9	9						16	2%
Chain Pickerel	<i>Esox niger</i>	10					1		3				17	2%
Spottail Shiner	<i>Notropis hudsonius</i>					2	3						21	1%
American Eel	<i>Anguilla rostrata</i>		1										22	1%
Total:		194	141	309	68	300	458	56	373	188	194	236	185	100%

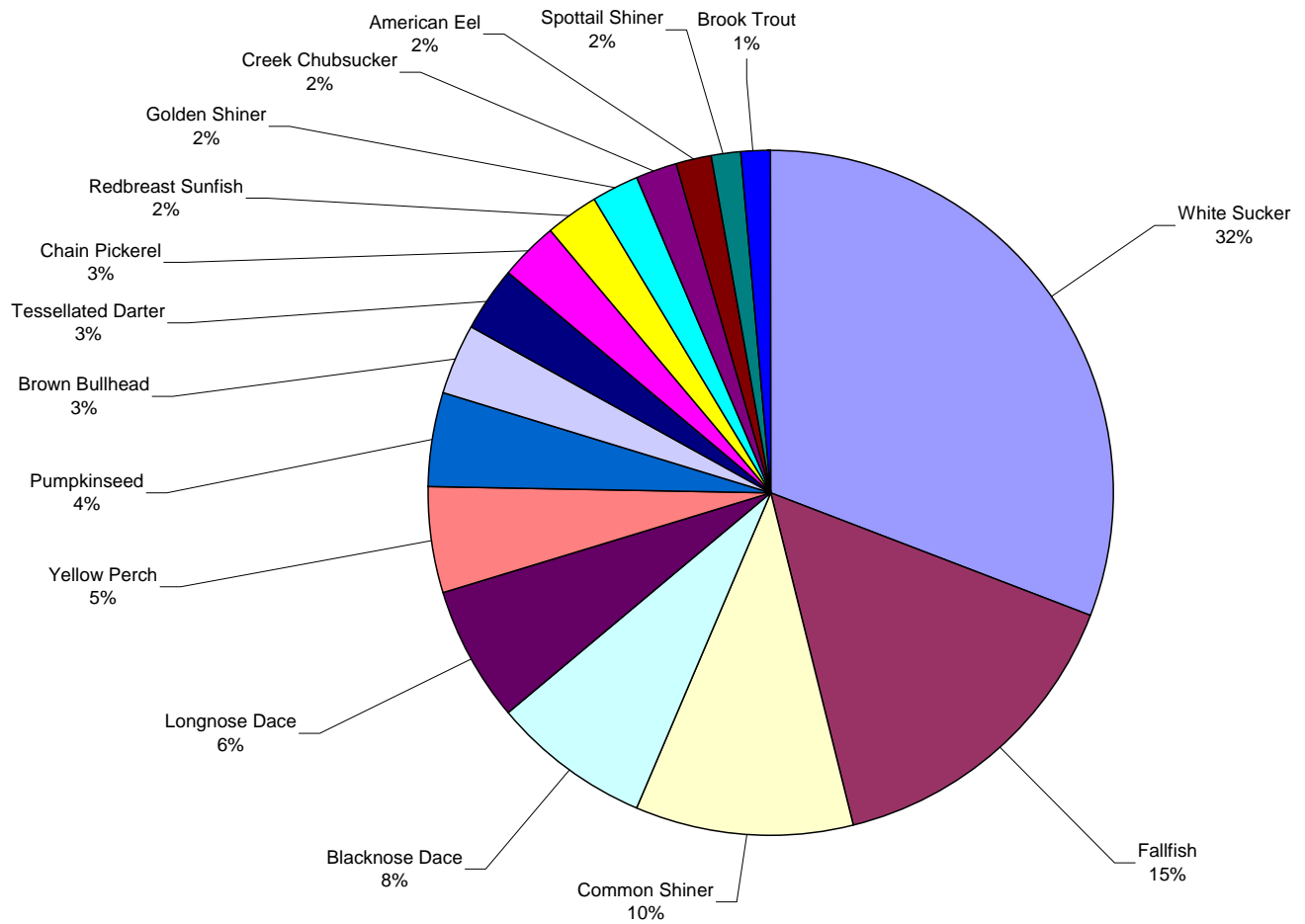


Figure 4. Lower Souhegan River Target Fish Community (L-TFC).

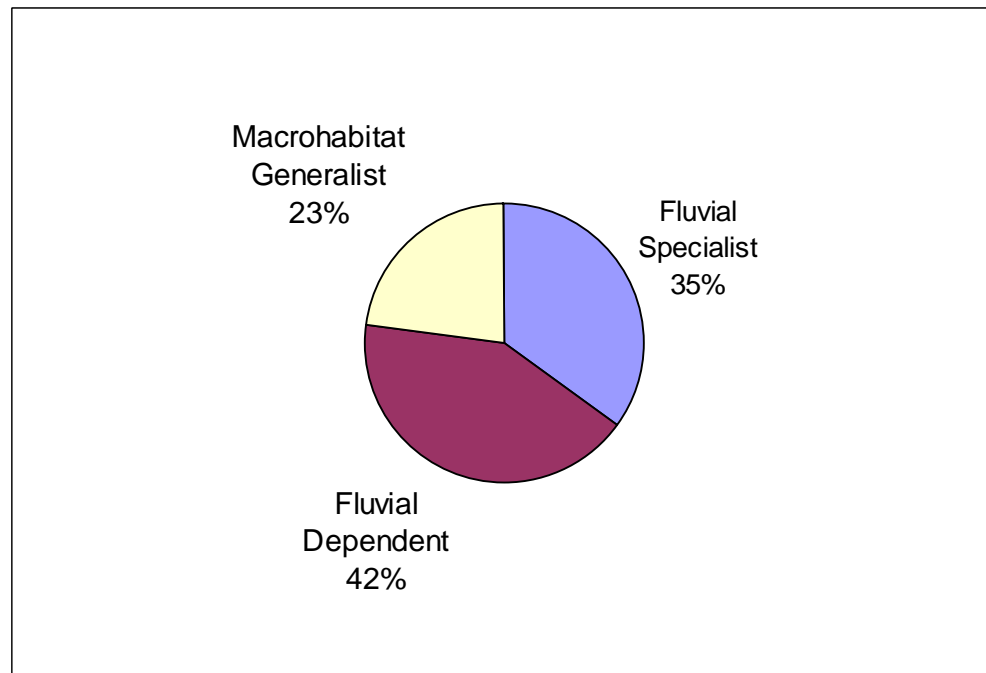


Figure 5. L-TFC based on habitat use classification guilds.

Table 5. Lower Souhegan River Target Fish Community species list with mean ranks and expected proportions of species.

Common Name	Scientific Name	Soucook River	Quaboag River	Quinnipiac River	Ware River	Willimantic River	Mean Rank	Expected Proportion
White Sucker	<i>Catostomus commersoni</i>	2	69	625	283	1092	1	31%
Fallfish	<i>Semotilus corporalis</i>	1	14	95	227	3194	2	15%
Common Shiner	<i>Luxilus cornutus</i>	100			32	1440	3	10%
Blacknose Dace	<i>Rhinichthys atratulus</i>	117	14		5	557	4	8%
Longnose Dace	<i>Rhinichthys cataractae</i>	53	69	225	70		5	6%
Yellow Perch	<i>Perca flavescens</i>		193	30	203	193	6	5%
Pumpkinseed	<i>Lepomis gibbosus</i>		208	10	96	50	7	4%
Brown Bullhead	<i>Ameiurus nebulosus</i>	2	138		14	2	9	3%
Tessellated Darter	<i>Etheostoma olmstedii</i>	2		135		104	10	3%
Chain Pickerel	<i>Esox niger</i>		128		9	7	11	3%
Redbreast Sunfish	<i>Lepomis auritus</i>		82			150	13	2%
Golden Shiner	<i>Notemigonus crysoleucas</i>		104		1	22	14	2%
Creek Chubsucker	<i>Erimyzon oblongus</i>		91		9		16	2%
American Eel	<i>Anguilla rostrata</i>	2		75		21	18	2%
Spottail Shiner	<i>Notropis hudsonius</i>	6				16	20	2%
Brook Trout	<i>Salvelinus fontinalis</i>	1		5			24	1%
Totals:		286	1110	1200	949	6848		100%

Upper Souhegan River Existing Fish Community

The existing fish community of the Upper Souhegan River, as sampled in the summer of 2005, was dominated by native fluvial species (87% fluvial specialist and 8% fluvial dependent), with a small proportion of macrohabitat generalists (5%). The community consisted of: blacknose dace (55%), longnose dace (25%), fallfish (6%), common shiner (5%), white sucker (3%), yellow perch (2%), largemouth bass (2%), and Atlantic salmon (1%). Pumpkinseed, golden shiner, and brown trout, combined, made up the remaining 1% of the community. A total of 11 different fish species were sampled in the Upper Souhegan River, nine of which were native. The only two non-native fish species sampled in the Upper Souhegan, largemouth bass and brown trout, accounted for less than 3% of the community (Figure 6).

Lower Souhegan River Existing Fish Community

The existing fish community of the Lower Souhegan River, also surveyed in the summer of 2005, was dominated by: common shiner (30%), fallfish (20%), blacknose dace (16%), white sucker (13%), redbreast sunfish (13%), longnose dace (4%), largemouth bass (2%) and golden shiner (1%). The Lower Souhegan fish community consisted of primarily native fluvial species (41% fluvial specialist and 43% fluvial dependent), with a considerably lesser proportion of macrohabitat generalists (16%). The remaining species, yellow bullhead, brown trout, creek chubsucker, chain pickerel, yellow perch, bluegill, rainbow trout, and pumpkinseed accounted for a combined total of less than 2% of the community. A total of 16 different fish species were sampled in the Lower Souhegan River, 11 of which were native. The five non-native species sampled in the Lower Souhegan, largemouth bass, yellow bullhead, brown trout, bluegill, and rainbow trout accounted for a combined total of less than 3% of the community (Figure 7).

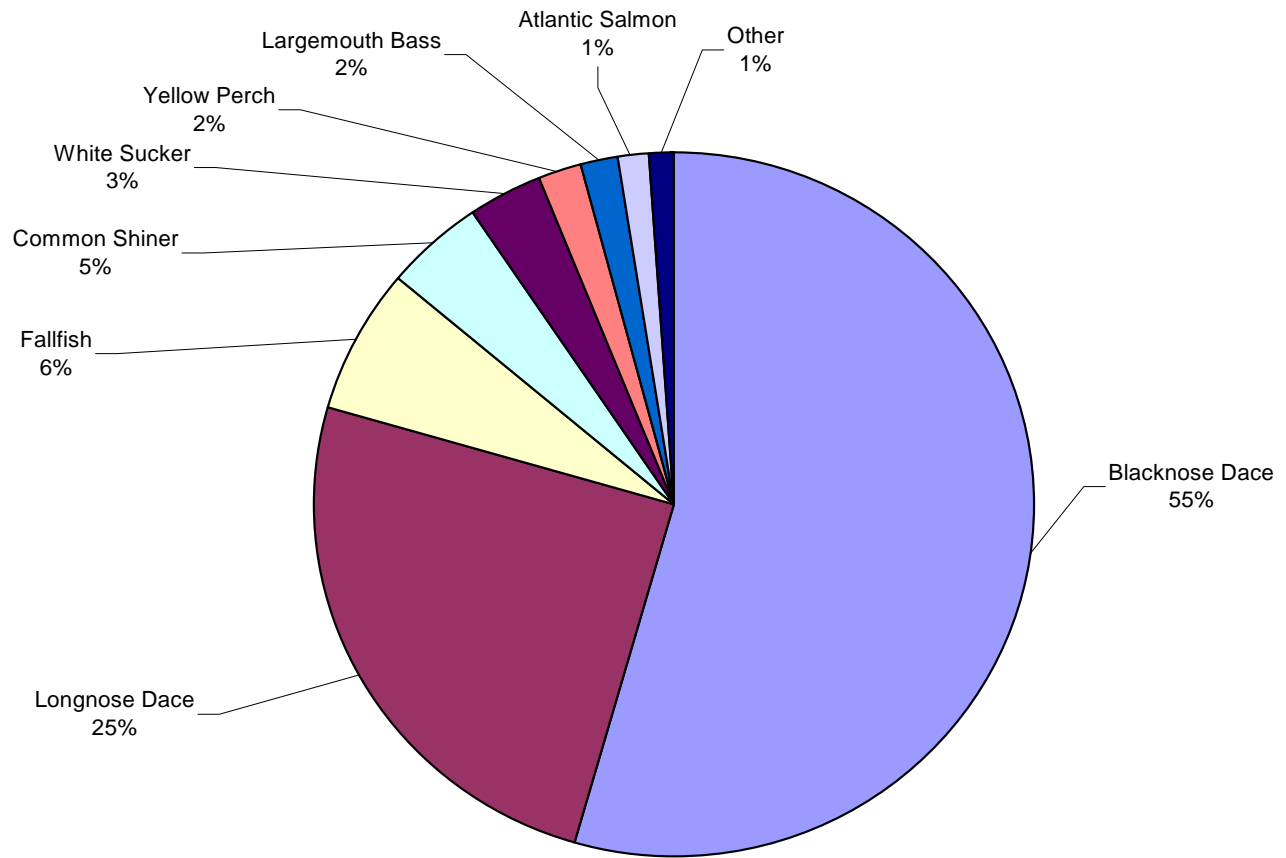


Figure 6. Upper Souhegan River existing fish community.

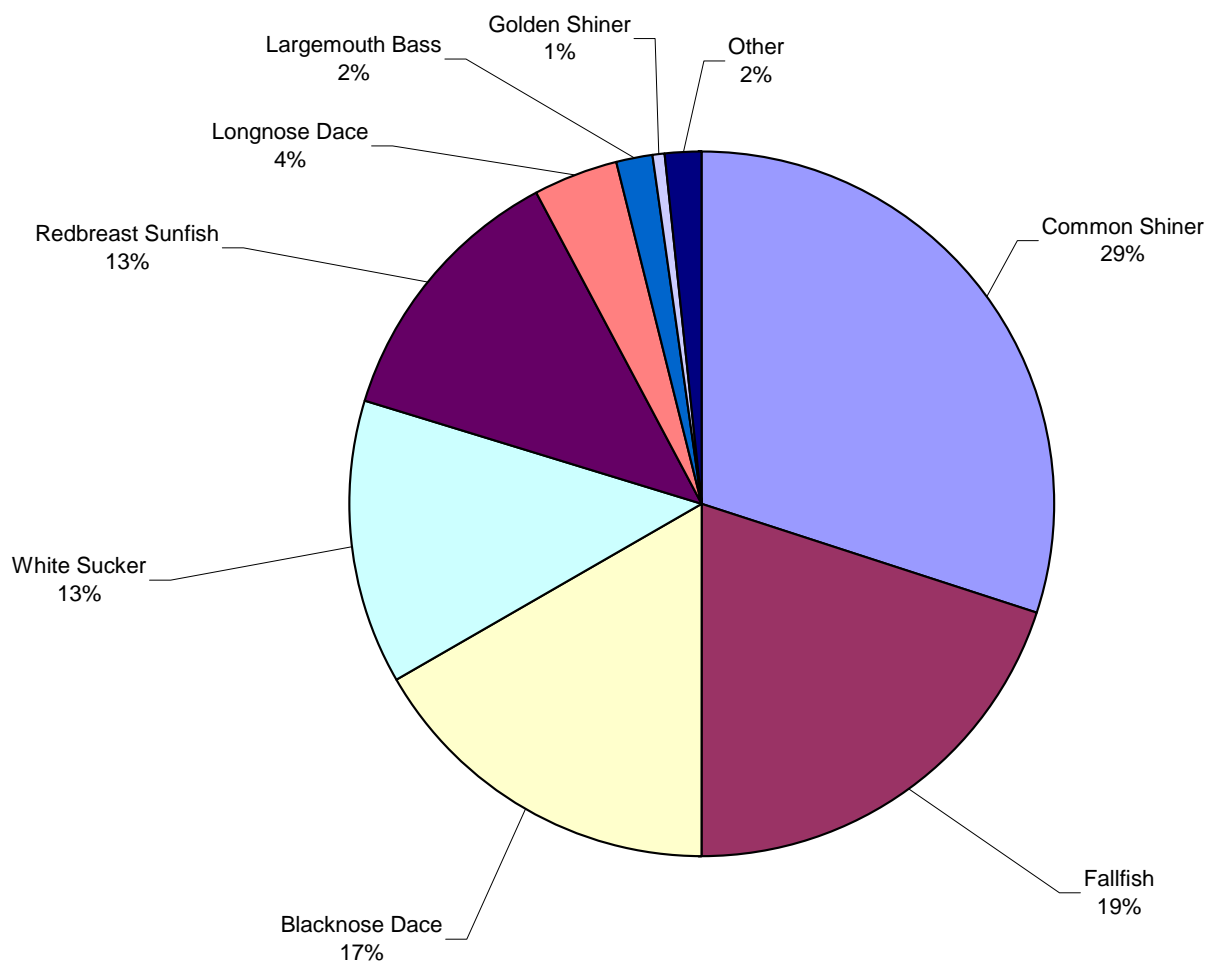


Figure 7. Lower Souhegan River existing fish community

Existing Fish Community Evaluations

A comparison of the similarity between the Upper Souhegan River fish community and the U-TFC was made using the percent model affinity procedure. The Upper Souhegan River fish community scored an affinity value of 61% similarity to the U-TFC. The Lower Souhegan River fish community scored an affinity index value of 54% similarity to the L-TFC. These affinity value indexes allow us to evaluate the fauna of the Souhegan River on a community scale. Community scale analyses were also conducted on proportions of species within the TFC and existing fish communities based on habitat use, pollution tolerance, and thermal regime classification guilds to further evaluate the status of the Souhegan River fish communities.

Comparison of the Upper Souhegan River existing fish community proportions to the U-TFC proportions based on habitat use guilds (Figure 8) revealed an underrepresentation of fluvial dependent and macrohabitat generalist species, and a slight overabundance of fluvial specialist species in the existing fish community. The most substantial of these deviations is the 69% difference between expected and existing proportions of macrohabitat generalist species. The differences between expected and existing proportions of fluvial specialist and fluvial dependent species are 30% and 55%, respectively.

The U-TFC consisted of 12% pollution intolerant species, 44% moderately tolerant species, and 44% tolerant species. The Upper Souhegan existing fish community was comprised of 1% pollution intolerant species, 40% moderately tolerant species, and 59% tolerant species (Figure 9). A comparison between the two communities illustrated an underrepresentation of pollution intolerant species in the existing fish community of the Upper Souhegan with proportions differing by 88%. Moderately tolerant species were considerably similar (8%), while pollution tolerant species were slightly overabundant in the existing community with a difference of 32% between the two communities.

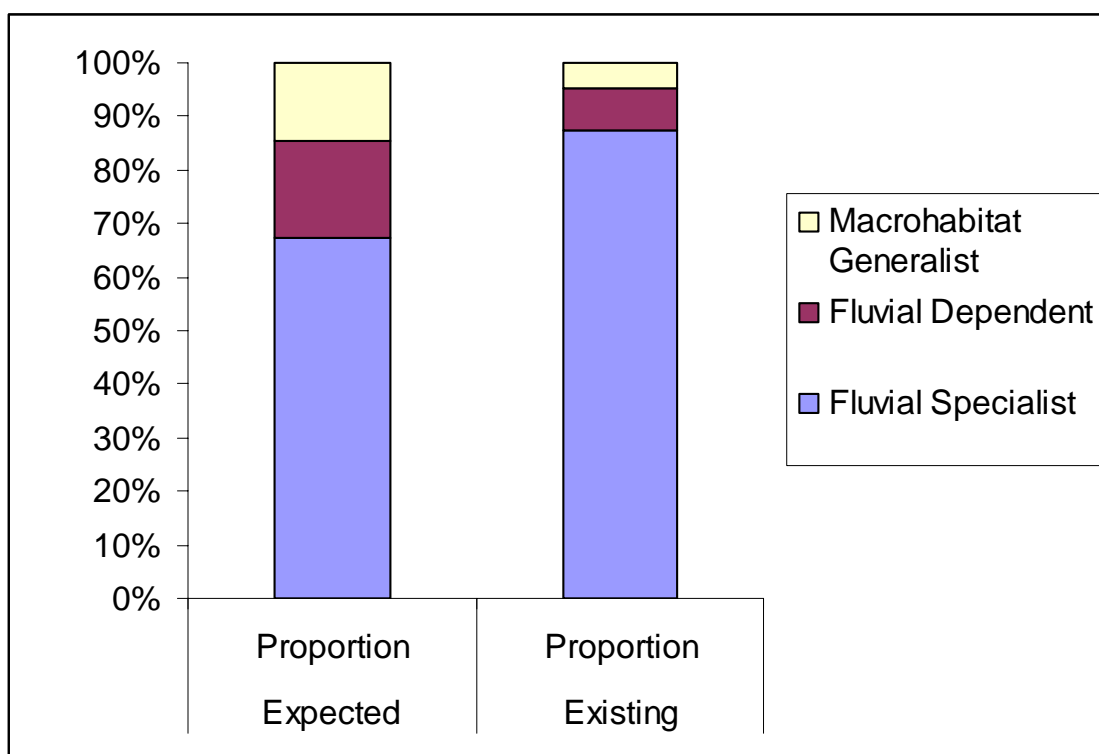


Figure 8. Comparison of the proportions of habitat use classification guilds between the U-TFC and Upper Souhegan River existing fish community.

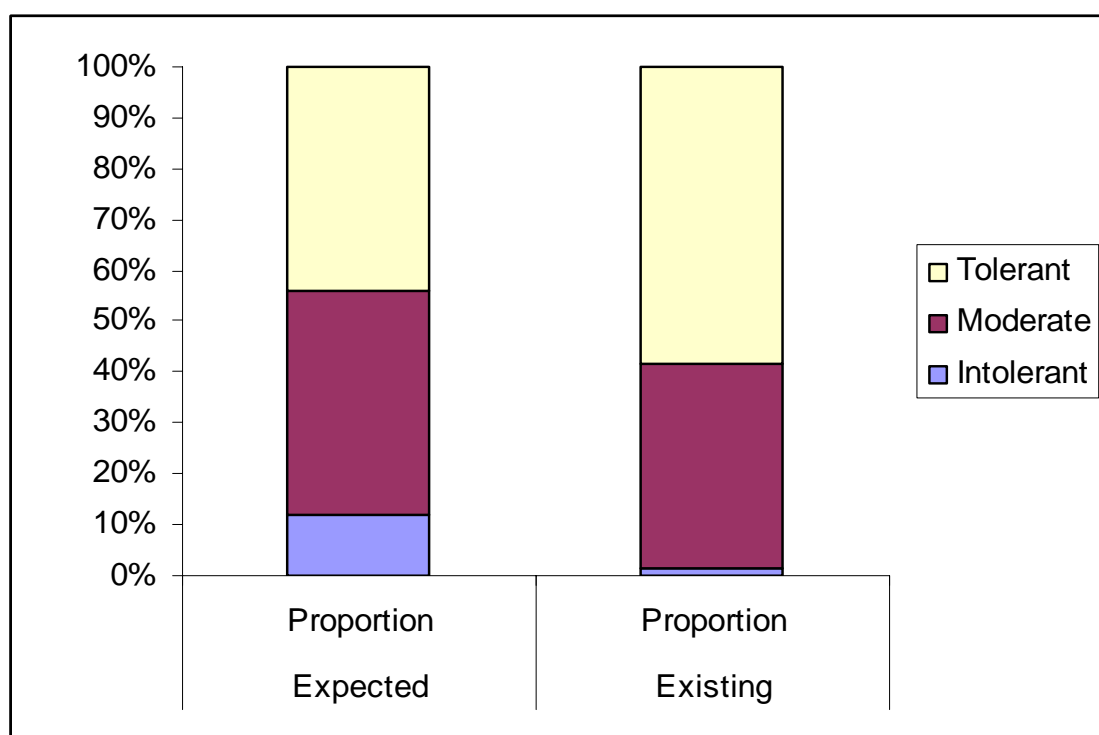


Figure 9. Comparison of the proportions of pollution tolerance classification guilds between the U-TFC and Upper Souhegan River existing fish community.

The U-TFC consisted of 16% cold water species, 75% cool water species, and 9% warm water species. The Upper Souhegan existing fish community was comprised of 1% cold water species, 97% cool water species, and 2% warm water species (Figure 10). Cool water species, or species tolerating a wide range of water temperatures from warm to cold, accounted for a major portion of both communities yet were slightly overabundant in the existing community. Conversely, cold water and warm water species accounted for considerably lesser portions of both communities and were both under-represented in the existing community. The greatest difference (92%) was between cold water species, followed by warm water (77%), and then cool water species (29%).

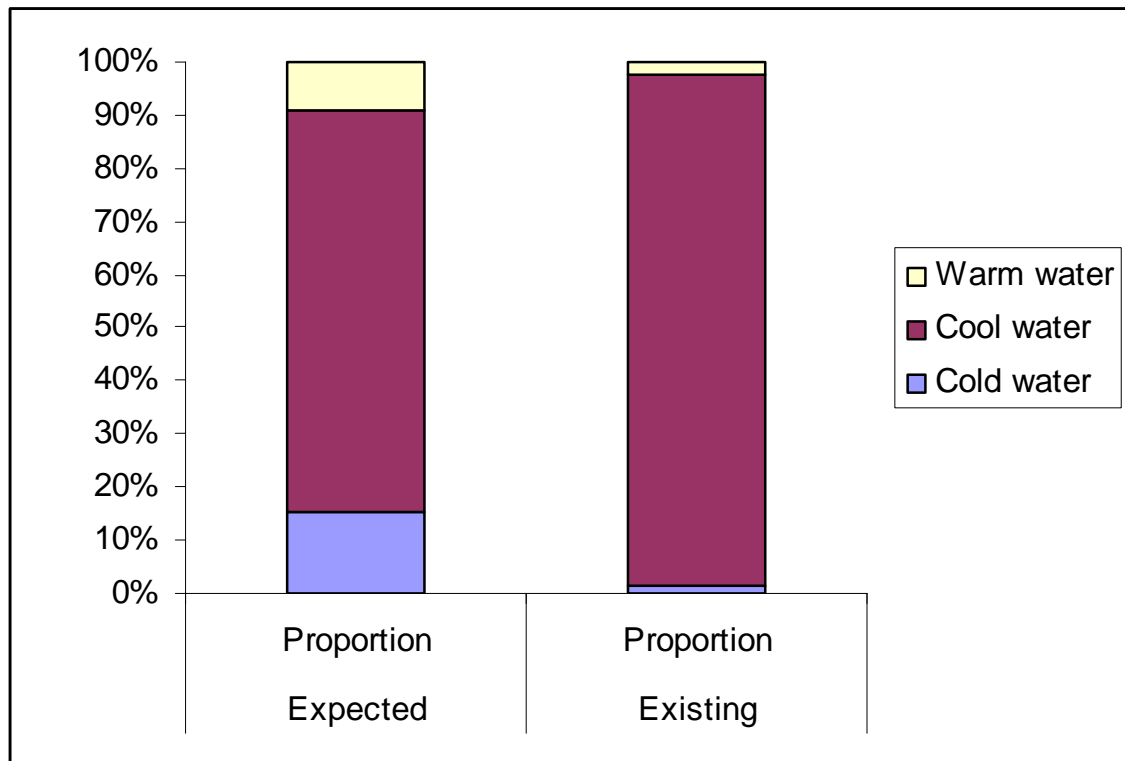


Figure 10. Comparison of the proportions of thermal regime classification guilds between the U-TFC and Upper Souhegan River existing fish community.

Comparison of the Lower Souhegan existing fish community to the L-TFC based on habitat use guilds (Figure 11) revealed a close similarity between the two communities. The most noteworthy difference (35%) was between the proportions of macrohabitat generalist species, which are slightly underrepresented in the existing community. Proportions of fluvial specialists were only slightly different (16%), while there was almost no difference between proportions of fluvial dependent species (4%).

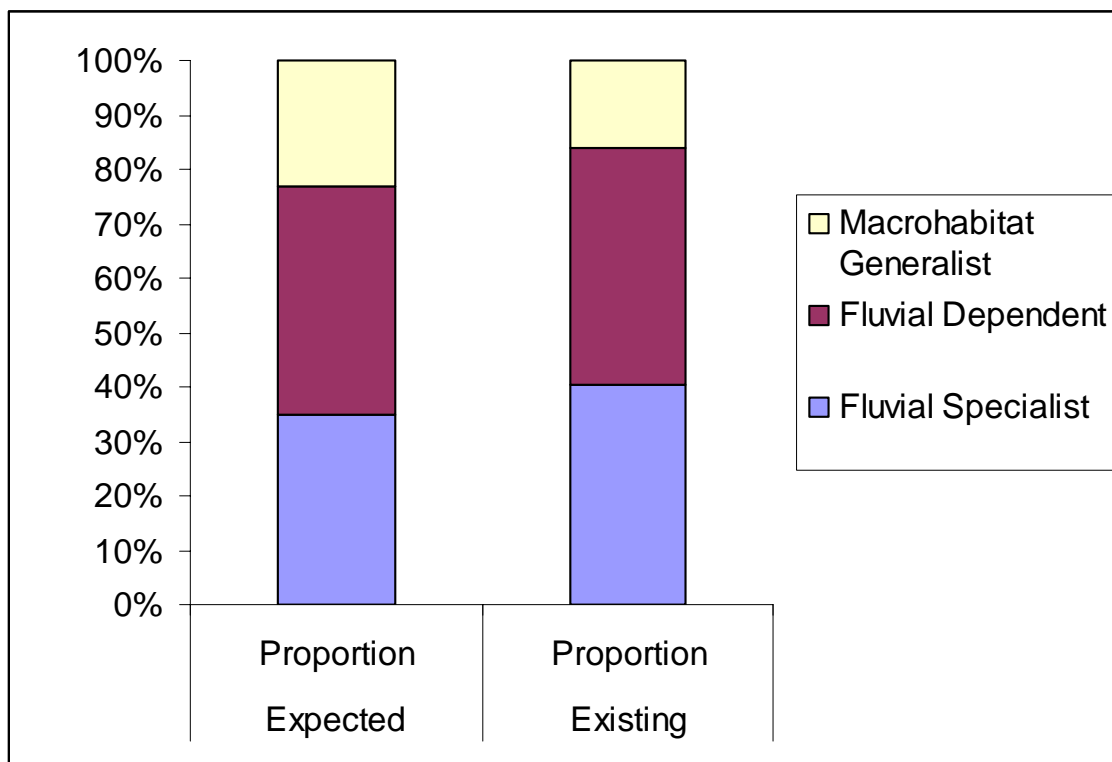


Figure 11. Comparison of the proportions of habitat use classification guilds between the L-TFC and Lower Souhegan River existing fish community.

The L-TFC consisted of 3% pollution intolerant species, 51% moderately tolerant species, and 46% tolerant species. The Lower Souhegan existing fish community was comprised of 1% pollution intolerant species, 68% moderately tolerant species, and 31% tolerant species (Figure 12). When the two communities were compared based on these pollution tolerance guilds, a considerable difference (79%) was found between the existing and target proportions of pollution intolerant species. Considerable differences were also noticed between the expected and existing proportions of moderately tolerant (34%) and tolerant species (33%). Existing proportions of moderately tolerant species were only slightly higher than expected whereas proportions of tolerant species were slightly lower. Existing proportions of intolerant species however were considerably lower than expected.

The L-TFC consisted of 1% cold water species, 86% cool water species, and 13% warm water species. The Lower Souhegan existing fish community was comprised of 0% cold water species, 85% cool water species, and 15% warm water species (Figure13). A comparison between the two communities illustrated an underrepresentation of cold water species in the existing fish community of the Lower Souhegan with proportions differing by 89%, despite having an absolute difference of only 1% accounted for by the absence of a single cold-water species (brook trout). The proportions of cool water species were almost identical, while proportions of warm water species were only slightly different (15%).

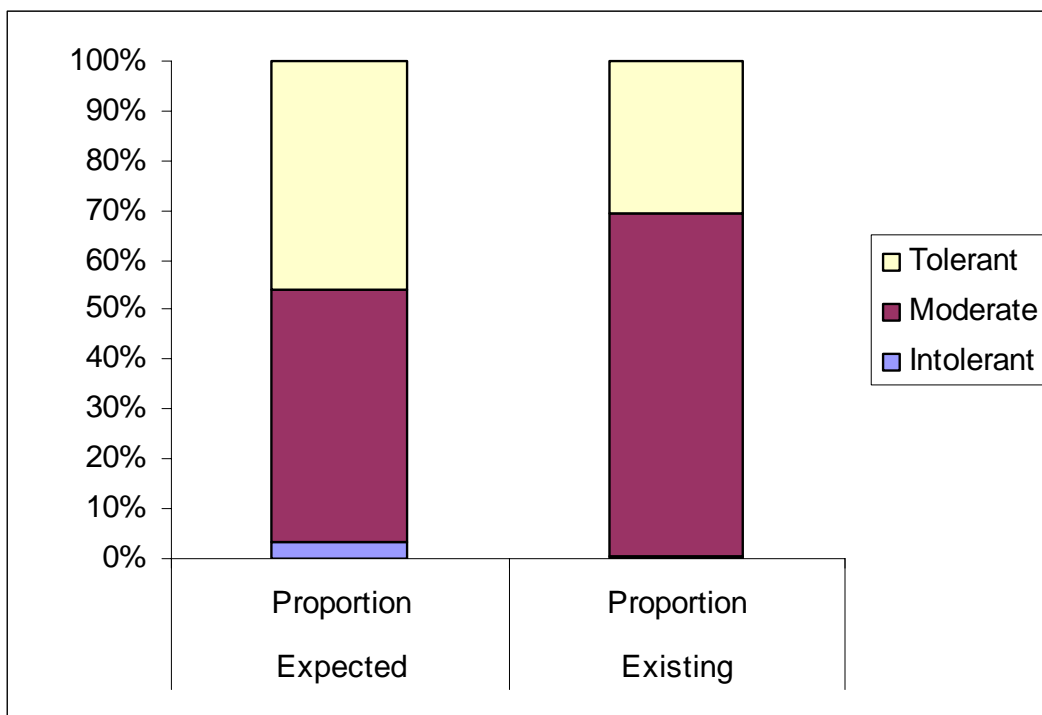


Figure 12. Comparison of the proportions of pollution tolerance classification guilds between the L-TFC and Lower Souhegan River existing fish community.

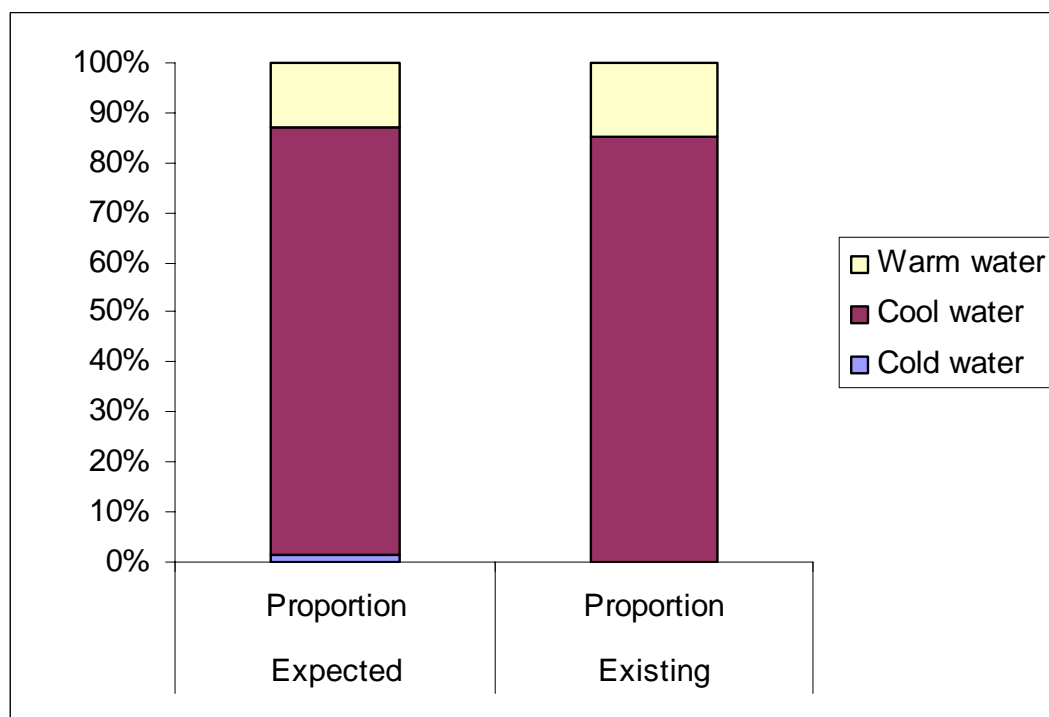


Figure 13. Comparison of the proportions of thermal regime classification guilds between the L-TFC and Lower Souhegan River existing fish community.

Differences between proportions of individual species in the TFC and the existing fish communities of the Souhegan River were analyzed using the calculated percentage differences between the expected (TFC) and existing proportions to evaluate the status of individual fish species within the river.

Within the Upper Souhegan River existing fish community, Atlantic salmon, common shiner, golden shiner, pumpkinseed and white sucker were determined to be underrepresented in the Upper Souhegan River existing fish community, while blacknose dace and longnose dace were found in greater abundances than predicted target community proportions. Brown trout and largemouth bass represented the only two non-natives in the Upper Souhegan fish community. (Table 6).

In the Lower Souhegan River existing fish community chain pickerel, creek chub sucker, pumpkinseed, yellow perch, and white sucker were found to be underrepresented, while blacknose dace, common shiner and redbreast sunfish were considered to be overrepresented. Introduced species existing in the Lower Souhegan River were bluegill, brown trout, largemouth bass, rainbow trout, and yellow bullhead. (Table 7).

Table 6. Comparison of proportions of fish species between the U-TFC⁴ and Upper Souhegan River existing fish community, identifying underrepresented, existing as expected, overly abundant, missing, and introduced species. Native (N) or introduced (I) statuses, fluvial specialist (FS), fluvial dependent (FD), or macrohabitat generalist (MG) habitat use classifications, intolerant (I), moderate (M), or tolerant (T) pollution tolerances, and Cold, Cool, or Warm water thermal regimes are given for each species.

Species	Proportion of Target Fish Community	Proportion of Existing Fish Community	Native or Introduced	Habitat use Classification	Pollution Tolerance	Thermal Regime
<i>Underrepresented native target fish species</i>						
Atlantic salmon	3%	1%	N	FS	I	Cold
Common shiner	10%	5%	N	FD	M	Cool
Golden shiner	2%	<1%	N	MG	T	Cool
Pumpkinseed	2%	<1%	N	MG	M	Warm
White sucker	7%	3%	N	FD	T	Cool
<i>Target fish species recorded as expected</i>						
Fallfish	6%	6%	N	FS	M	Cool
Yellow perch	2%	2%	N	MG	M	Cool
<i>Overly abundant native target fish species</i>						
Blacknose dace	29%	55%	N	FS	T	Cool
Longnose dace	15%	25%	N	FS	M	Cool
<i>Missing native target fish species</i>						
American eel	1%	0%	N	FD	T	Cool
Brown bullhead	2%	0%	N	MG	T	Warm
Chain pickerel	2%	0%	N	MG	M	Warm
Creek chub	2%	0%	N	FS	T	Cool
Eastern brook trout	4%	0%	N	FS	I	Cold
Longnose sucker	4%	0%	N	FS	M	Cold
Redbreast sunfish	3%	0%	N	MG	M	Warm
Slimy sculpin	5%	0%	N	FS	I	Cold
Spottail shiner	1%	0%	N	MG	M	Cool
<i>Introduced species present in the existing fish community</i>						
Brown trout	0%	<1%	I	FD	I	Cool
Largemouth bass	0%	2%	I	MG	M	Warm

⁴ Proportions of American eel and Atlantic salmon may be under-represented in the TFC due to the regional decline and extirpation, respectively, of these diadromous species. Proportions of Cold-water species may or may not be appropriate for the Upper Souhegan River due to uncertain historical distributions.

Table 7. Comparison of proportions of fish species between the L-TFC and Lower Souhegan River existing fish community, identifying underrepresented, existing as expected, overly abundant, missing, and introduced species. Native (N) or introduced (I) statuses, fluvial specialist (FS), fluvial dependent (FD), or macrohabitat generalist (MG) habitat use classifications, intolerant (I), moderate (M), or tolerant (T) pollution tolerances, and Cold, Cool, or Warm water thermal regimes are given for each species.

Species	Proportion of Target Fish Community	Proportion of Existing Fish Community	Native or Introduced	Habitat use Classification	Pollution Tolerance	Thermal Regime
<i>Underrepresented native target fish species</i>						
Chain pickerel	3%	<1%	N	MG	M	Warm
Creek chubsucker	2%	<1%	N	FS	I	Cool
Pumpkinseed	4%	<1%	N	MG	M	Warm
Yellow perch	5%	<1%	N	MG	M	Cool
White sucker	31%	13%	N	FD	T	Cool
<i>Target fish species recorded as expected</i>						
Fallfish	15%	20%	N	FS	M	Cool
Golden shiner	2%	1%	N	MG	T	Cool
Longnose dace	6%	4%	N	FS	M	Cool
<i>Overly abundant native target fish species</i>						
Blacknose dace	8%	17%	N	FS	T	Cool
Common shiner	10%	30%	N	FD	M	Cool
Redbreast sunfish	2%	13%	N	MG	M	Warm
<i>Missing native target fish species</i>						
American eel	2%	0%	N	FD	T	Cool
Brown bullhead	3%	0%	N	MG	T	Warm
Eastern brook trout	1%	0%	N	FS	I	Cold
Spottail shiner	2%	0%	N	MG	M	Cool
Tessellated darter	3%	0%	N	FS	M	Cool
<i>Introduced species present in the existing fish community</i>						
Bluegill	NA	<1%	I	MG	T	Warm
Brown trout	NA	<1%	I	FD	I	Cool
Largemouth bass	NA	2%	I	MG	M	Warm
Rainbow trout	NA	<1%	I	FD	I	Cold
Yellow bullhead	NA	<1%	I	MG	T	Warm

Discussion

The Target Fish Communities developed for the Souhegan River provide a method for evaluating the existing fish communities of the Upper and Lower portions of the river. They are similar to previous target fish communities developed for other rivers within the region (Bain and Meixler, 2000; Kearns et al. 2004; Meixler, 2005) in their composition of fluvial and macrohabitat generalist species, are feasible, attainable, and instrumental to the evaluation of the status of flow dependent fish species within the Souhegan River.

Development of a list of species known to occur or with the potential to occur, within the Souhegan, was accomplished based on a review of recent and historical fish collection records, detailed distribution descriptions, watershed and fisheries management objectives, and factors contributing to potential future introductions or inhabitations of the river by non-indigenous fish. Recent collection records from the Souhegan River and its tributaries, presented in a report on the flow dependent resources of the river (NAI, 2004), provided an initial list of fish species known to occur within the Souhegan River watershed. This list was supplemented by a review of two of the primary sources on the fishes of New Hampshire and Massachusetts (Scarola, 1987; Hartel et al., 2002) to identify species that are known to occur within the waters of the Souhegan River region. Historic records or accounts were investigated to confirm the past presence of fish species believed to have been extirpated from the river (e.g. anadromous species) (Livermore and Putnam, 1888). Finally, detailed distribution information on the fishes of the Northeastern United States on a regional (Halliwell et al., 1999) and watershed scale (Schmidt, 1986; Hartel et al., 2002) were reviewed to identify missing species or mediate conflicting distribution accounts. The final list is indicative of the assortment of established fish species found within this region and reflective of the different ecoregional zones within which the Souhegan River occurs (Halliwell et al., 1999). For example, the list includes both slimy sculpin and swamp darter, species limited to the Northeastern Highlands (Upper Souhegan) and Northern Coastal Plains (Lower Souhegan) ecoregions, respectively (Omernik, 1987; Halliwell et al., 1999).

Conflicting distribution accounts led to controversy over the inclusion of some species not recorded in recent collection records within the watershed. Tessellated darter, for example, was not collected within any of the Souhegan watershed samples presented in the Instream Protected Uses and Outstanding Resources of the Souhegan River (2004) report, nor was the Merrimack River watershed considered part of its natural distribution by Scarola (1987) or Schmidt (1987). However, tessellated darter was included in the L-TFC as a result of the presence of this species in a sample from the Soucook River, a tributary of the Merrimack. It is considered native to both the Merrimack and Nashua (a tributary of the Merrimack River having a source in very near proximity to the source of the Souhegan, beginning within the Northern Highlands, and flowing through the Northeastern Coastal plains ecoregion to its confluence with the Merrimack just south of the Souhegan) Rivers by Hartel et al. (2002). Slimy sculpin, a cold-water-dependent species, was also included in the final list, despite the absence of this species from recent collection records, due to its consideration as native to and historically present within the Merrimack drainage (Schmidt, 1987; Hartel et al., 2002). Two other cold-water dependent species, brook trout and longnose sucker, which were not found within the Souhegan River but were present within some of the reference rivers, were also included.

Anadromous species were also included due to the United States Fish and Wildlife Service's inclusion of the Souhegan River in their efforts to restore Atlantic salmon and American shad to the Merrimack River. Further supporting this decision was the proposed removal of the Merrimack Village Dam, which would provide anadromous fish with access to the Souhegan River and its tributaries as far upstream as Milford, New Hampshire and an historical account given in the Wilton Town History which stated that "alewives, shad and salmon penetrated as high up the river as Greenville...as late as 1773-4" (Livermore and Putnam, 1888).

The inclusion of anadromous species in the list of potential species imposes a dilemma when using Target Fish Communities to evaluate the status of fauna existing within a river. The problem is one that was acknowledged by Bain and Meixler (2000) in their initial development of a TFC when they noted that reference rivers "...were not in a natural or fully pristine state but instead were recognized as the best source for data..." relative to the study river. Accounting for proportions of anadromous species is difficult if not impossible since many have experienced range-wide extirpations or decline and no longer exist in their natural or historic proportions even within relatively unimpacted potential reference rivers. One solution would be to take the TFC method one step further through the development of a Reference Fish Community (RFC). A RFC would include all species that historically existed within the watershed but have since been extirpated (e.g. anadromous fishes), and would account for proportional differences of those species that may be currently underrepresented, such as Atlantic salmon. The expected proportions of these species would be computed using expert-opinion-based ranking within the community. Development of a scientific approach to this concept may prove critical as state agencies begin to adopt TFC methodology as policy and management practices given the importance of anadromous fish restoration within this region and throughout. Such an approach could serve to improve the versatility of TFC application while providing the means necessary to identify management targets and evaluate restoration efforts. Identification of target proportions for these species may also provide guidance for the restoration and management of habitats that may be critical to future recoveries or re-establishments of these populations.

Overall, the Upper and Lower Souhegan River fish communities were similar to the respective TFC models developed for these portions of the river. However fish densities in the Upper Souhegan samples were considerably lower than in previous studies conducted using the same collection method on the Pomperaug, and Eightmile Rivers in Connecticut. The affinity values measured for the Upper and Lower Souhegan River, 61% and 54%, respectively, were considerably higher than those found in similar studies (Bain and Meixler, 2000; Kearns et al., 2005; Meixler, 2005). While this may be indicative of fish communities that are less impacted than others that have been investigated using the TFC method, it may also reflect improvements in the selection of appropriate reference rivers. The Reference River Selection Model, developed and applied for the first time on this project, has proven to be an effective and efficient method of selecting reference rivers. The ability to select different, or additional criteria attributes, or to specify or generalize the parameters of those criterion, make it a versatile tool that can be applied to develop TFC models for multiple different stream types without limits to zoo-geographic regionality or physical habitat conditions. The capacity of the RRSModel to select reference rivers possessing physical characteristics that are highly similar to the those of a study river may result in the development of a TFC model that more appropriately represents the potential fish community of that river. However, regardless of physical and zoo-geographic similarities, there is often a

great deal of variation between the fish assemblages (with regard to species composition and proportions) of otherwise highly similar rivers. In this respect, it may be important, when conducting a TFC study, to evaluate the fish communities based, not only on an affinity measure of the differences or similarities of species, but as well as on affinity measures of: habitat use, pollution tolerance, and thermal regime guilds. Such measures in this study revealed that the differences between the TFC models and the existing fish communities, when compared based on the species habitat use guilds, were minimal. Greater differences were noticed when the affinities of these communities were measured based on species thermal regime tolerances. Measures based on these guilds allow for inferences into potential causes for deviations from the TFC to be made, while differences between species compositions alone may be merely coincidental, the result of biogeographic distributional patterns or other circumstances which may not be evident or easily explained. When both comparisons between specific species and guilds of species types are compared together, an evaluation of the status of a fish community may be more accurately assessed than if either comparison were considered alone.

In the Upper Souhegan River proportions of blacknose dace and longnose dace (fluvial specialist species) were substantially higher than expected while proportions of white sucker and common shiner (fluvial dependent species) were considerably lower. A possible reason for this may be the fragmentation of habitats created by multiple dams located along the mainstem of the Souhegan River. Such fragmentation of habitats could severely limit proportions of common shiner and white sucker as both of these species are required to make migrations to and from suitable upstream spawning locations as juvenile and adult habitat requirements differ for those life-stages of these species (Scarola, 1987; Hartel et al., 2000). Pollution intolerant and cold-water species (Atlantic salmon, brook trout, and slimy sculpin) were missing from the Upper Souhegan with the exception of the small proportion (1%) of stocked juvenile Atlantic salmon. Temperature measurements taken in the Souhegan River while electrofishing, by instream monitors, throughout the main stem of the Souhegan River over the past two summers (2004-2005), and at the outflow of impoundments along the river and its tributaries during field visits (August, 2005) (Souhegan PISF Report) revealed multiple occurrences and extended time periods of water temperatures exceeding the thermal tolerances of these cold-water species (Lyons et al., 1996; Karas, 1997). Given these measurements of temperatures exceeding the tolerances of cold-water fish species, and the fact that pollution tolerant species were only slightly higher than target proportions, it would appear that thermal conditions, not pollution, could explain the near absence of those pollution intolerant, cold-water-dependent species (Atlantic salmon, brook trout, and slimy sculpin). The three coldwater fish species which were missing from the Upper Souhegan River, brook trout, longnose sucker and slimy sculpin, were also missing completely from three of the eleven upper reference rivers. Only two of the eleven upper reference rivers (the Cold River and Chickley River, both tributaries of the Deerfield River in Connecticut River watershed of Massachusetts) contained all three of these species. Three of the upper reference rivers contained only two of these species, brook trout and slimy sculpin, while the three other rivers contained only one of these cold-water species, longnose sucker in two of them, and brook trout in the third (Table 4). During the course of this study some concerns were raised as to the validity of the longnose sucker identifications from two of the reference rivers, the Middle and South Branches of the Piscataquog River. While both of these rivers contained Atlantic salmon, suggesting that they may be capable of supporting coldwater species, they

did not contain either of the other two cold-water species (brook trout or slimy sculpin) leading to further speculation on the validity of the longnose sucker samples from those locations. This speculation, combined with the documentation of a more northerly limited distribution of this species within the state of New Hampshire (Scarola, 1987), creates some uncertainty about the proportion of this species within the U-TFC. A lack of vouchers from the Piscataquog River samples left us unable to confirm or reject these speculations. As a result this uncertainty should be considered when viewing these results. Similar attention was given to the proportions of the other two cold-water species, brook trout and slimy sculpin, within the U-TFC. The lack of these species in many of the reference rivers (five), especially from the two nearest to the Souhegan River (the Middle and South branches of the Piscataquog) raised some apprehension as to the appropriateness of these species and their proportions in the U-TFC. However, we believe that their absences in the Souhegan River can be explained by the temperature regime of this river, as the region of the Upper Souhegan River and the Northeastern Highlands Ecoregion (Ecoregion 58) are considered to be within the distributional ranges of both of these species (Schmidt, 1986; Scarola, 1987). Further, it is likely that historical conditions may have contributed to the absence of these species from many of the reference rivers as well as other rivers throughout the region. For example, there is evidence to suggest that the patchy distributions of cold-water fish species throughout New England may be the result of anthropogenically induced local extirpations caused by lethal water temperature regimes resulting from the land use practices (e.g. deforestation, dam building) associated with the period of European colonization (Schmidt, 1986). This scenario could explain the drastic differences between the composition of these species among the Upper Souhegan reference rivers. It is perhaps interesting to note that the only two reference rivers containing all three of the coldwater species absent from the Upper Souhegan, (brook trout, longnose sucker, and slimy sculpin) were the Chickley River and Cold River, and these two rivers occur within one of the few areas within the region know to contain stands of old growth forest (A. D'Amato, UMass, Department of Natural Resources Conservation, personal communication). As a result, we feel that cold-water species in general are indeed under-represented within the Upper Souhegan River, despite the existing uncertainties of the proportions of these species within the U-TFC. Temperature data collected during the Souhegan PISF study, and documented within the PISF Report, revealed that water temperatures within the Upper Souhegan River were consistently higher than the upper thermal tolerance limits of these species and supports this assumption.

In the Lower Souhegan River the proportion of white sucker was considerably less than the L-TFC proportion. Results of habitat suitability modeling for white sucker using MesoHABSIM identified a majority of the suitable spawning habitat for this species within the Upper Souhegan River while the majority of suitable adult habitat was located within the Lower Souhegan (Souhegan PISF). Dams between the Upper and Lower portions of this river prevent mature white suckers within the Lower Souhegan from accessing the spawning habitat within the Upper portions of the river. The limited amounts of suitable spawning habitat in the Lower Souhegan River and the fish passage barriers preventing access to suitable upstream spawning habitat may be limiting proportions of white suckers in the Lower Souhegan. Despite the under-abundance of white sucker, proportions of fluvial dependent species as a whole were nearly identical to target proportions. Fluvial specialist and macrohabitat generalist species guild proportions were also similar to target proportions resulting in an overall similarity between the two communities based on habitat use

classification guilds. The only noteworthy differences between target proportions and existing proportions with regard to thermal regime and pollution tolerance classification guilds were among cold-water species and pollution intolerant species, both of which were underrepresented (nearly absent) in the existing fish community. The actual deviation between both cold-water and pollution intolerant species can be accounted for by one species, brook trout, which is both cold-water dependent and pollution intolerant, and may not be appropriate in the L-TFC. Even under pristine conditions, the Lower Souhegan River may not have supported the 1% proportion of brook trout proposed by the L-TFC. Regardless, it is fair to say that the absence of brook trout, creating an absolute difference of only 1% between both the cold-water and pollution intolerant guilds of the two communities, does not necessarily imply a definite problem in the Lower Souhegan with regard to water temperature or pollution.

The Target Fish Communities developed for the Souhegan River were successful in their identification of community structures to serve as a reference model for the structure of the existing communities within the river. By comparing the existing community structures to these models we were able to identify deviations of individual species. Further comparisons based on the habitat uses, pollution tolerances, and thermal requirements of these species allowed us to identify possible reasons for departures from target conditions with regard to flow regime and water quality and condition. Water quality and condition appear to have a greater impact than flow conditions on the fish community structure of the Souhegan River based on the structure of these communities at the time of our survey. This report provides an assessment of the current conditions of the Upper and Lower Souhegan River fish communities and a foundation for comparison to future evaluations of these communities and investigations into factors such as, instream flow, habitat, and water quality and condition which may affect their structure. The TFC models developed for the Upper and Lower Souhegan River also provided the information necessary to select the native fluvial fish species that would be considered in the MesoHABSIM modeling process for the Souhegan River Protected Instream Flow Study. The most abundant fluvial species from the U-TFC and L-TFC are selected for their ability to provide useful information with regard to instream flow sensitivity. Five species (blacknose dace, common shiner, longnose dace, fallfish, and white sucker), while occurring in different ranks and proportions, were the most common species within the TFC models for both the Upper and Lower river. These species were then weighted based these proportions for use within MesoHabitat Simulation Models (MesoHABSIM) (Parasiewicz, 2001) for the Upper and Lower Souhegan River (Souhegan River PISF Report)

The addition of the Reference River Selection Model to the TFC methodology may prove to be a useful contribution to future TFC applications. An approach to determine the degree to which a study stream is impacted (i.e., slightly impacted, moderately impacted, severely impacted, etc.) based on affinity values would also serve to enhance the effectiveness of TFC evaluations. As the methodology becomes more widely and frequently utilized, and the body of TFC literature and data increases, such an approach will likely evolve.

One technical aspect that should be considered in the above comparisons is the use of observed relative abundances of fish as an estimate of existing community structure. Although this method is proposed by Bain and Meixler and used in several subsequent studies it may be accompanied by considerable uncertainty. The data collected during one fish

ecological survey represents only a one small snapshot of the fish community. The representativeness of this sample strongly depends on temporal, spatial and technical issues such as number of samples, gear used for fishing, weather, and past hydrologic conditions. Subsequently, the community structure represented by observed relative abundances does not follow the power law distribution, as does TFC model⁵. This creates a source of mathematical error when a comparison is made between the TFC model and the existing fish community. One option to take these aspects into account is to apply the same weighted ranking routine to the sampled fish data as is used in the Target Fish Community model and consider the surveyed data for what it actually is: a sample of the existing fish community. Similarly for the RFC concept proposed earlier, due to the experimental nature of this method the results presented here do not include this existing fish community model but rather follow published and widely recognized methods. However, the reader should be aware of these caveats and consider options available for future improvements.

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⁵ The underlying assumption of the TFC model is that distribution of species in the community follows a power law.

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